



Defence Research and
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The Complexity Tutorial Workshop 2006

Final Report

M. Couture

R. Charpentier

DRDC Valcartier

Defence R&D Canada – Valcartier

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The Complexity Tutorial Workshop 2006

Final Report

M. Couture
R. Charpentier
DRDC Valcartier

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Principal Author

Mario Couture
Defence Scientist

Approved by

Guy Turcotte
Section Head, System of Systems, DRDC Valcartier

Approved for release by

Christian Carrier
Chief Scientist, DRDC Valcartier

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Abstract

This document provides a description of the Complexity Tutorial/Workshop 2006 event that was held on December 6th, 7th and 8th, 2006 at DRDC-RDDC Valcartier. Outcomes of the event, future works and conclusions are included.

Résumé

Ce document donne une description de l'événement « Complexity Tutorial Workshop 2006 » qui a eu lieu les 6, 7 et 8 décembre 2006 à DRDC-RDDC Valcartier. Les résultats de l'événement, travaux futurs et conclusions sont également inclus.

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Table of contents

Abstract	i
Résumé	i
Table of contents	iii
List of figures	iv
List of tables	v
Acknowledgements	vi
1 Introduction.....	1
2 The Complexity Tutorial Workshop 2006.....	2
2.1 The Tutorial	2
2.2 The ½-day workshop	5
3 Outcomes of the CTW-2006 event	7
3.1 Questions of participants	7
3.2 Comments on the tutorial	8
3.3 New avenues of national collaborations and R&D.....	9
3.4 Supplementary material – The CTW-2006 CD-ROM.....	10
3.5 Comments on the CTW-2006, and contributors.....	11
3.6 Valcartier Online and Leo Online	11
4 Concluding remarks and future works.....	13
References	14
Annex A – List of participants	15
Annex B – Syllabus of the Tutorial and reference material	17
Annex C – Pictures of the CTW-2006 event.....	18
Distribution list	19

List of figures

Figure 1. From left to right: R. Charpentier, Y. Bar-Yam and M. Couture.....	18
Figure 2. The CTW-2006 classroom.....	18

List of tables

Table 1. Six avenues of R&D	10
Table 2. Content of the CTW-2006 CD-ROM.....	10
Table 3. List of participants.....	15

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1 Introduction

Dr. Bar-Yam's tutorial Introduction is reproduced in the following two paragraphs. It introduces this course by briefly describing a new problematic, which can be addressed by considering concepts from Complexity Theory.

As the nature of modern conflict changes and technology advances, military operations are increasing in complexity across all domains. Soldiers must be able to identify enemy combatants hiding in urban environments and confront hazards like IEDs. Commanders have to deal with huge amounts of information and intelligence, and coordinate the actions of many small teams with diverse objectives. Military engineers and scientists need to anticipate soldiers' constantly changing needs and design incredibly complex systems that are robust and reliable.

*Recent finding of complexity science carry important implications for all of these military domains. This **two-day tutorial** will introduce the concepts and methods of complexity theory and show their application to current and future military issues. Topics to be covered include quantifying complexity, emergent behaviors, pattern formation, distributed control structures and networks, and the evolution of complex systems. Specific applications will be to military command and control structures, terrorism and security, predicting locations of violence, and new models of the engineering process.*

The Complexity Tutorial/Workshop 2006 aimed at providing DRDC-RDDC scientists and policy makers a minimum level of knowledge of Complexity Theory that would help them make a better use of concepts of this science in their own R&D efforts. It also aimed at favoring new collaborations between DRDC-RDDC organizations and people and identify/propose new areas of R&D that will eventually help military better address current (and future) complex problems they are facing.

2 The Complexity Tutorial Workshop 2006

The Complexity Tutorial/Workshop 2006 consisted of two different but complementary parts:

- a 2-day Tutorial on the basic concepts
- a 1/2 –day Workshop in which 30 people from different organizations of the DRDC-RDDC participated. (The list of participants is included in Annex B).

2.1 The Tutorial

The Tutorial was given by the President and Professor of the New England Complex Systems Institute (<http://www.necsi.org>); Professor Yaneer Bar-Yam. It was held on December 6th and 7th of 2006. (Annex C lists the contents of the Tutorial).

The main goals of this Tutorial are described in the following lines.

- Propose participants one vision of Complexity Theory, the one of an internationally recognized expert in the domain of Complexity Theory.
- Provide participants with the description of a selected number of concepts of Complexity Theory. This knowledge should bring participants to the same level of understanding of this theory.
- Discuss the results of past studies of real life applications of Complexity Theory.
- Maintain equilibrium between too detailed descriptions and over-generalization.

Some of the topics that were presented by Professor Bar-Yam are listed in the following lines. These are the writer's notes.

- Three approaches for thinking about complex systems
 - ◆ Interactions
 - ◆ How to describe complex systems
 - ◆ How to create systems that are able to evolve with respect of time
- Feedback
- Methods that are often used
 - ◆ M&S, Analytic, Conceptual, Agent, Cellular, Coupled networked map, Generative models, Monte Carlo, Many others
- How we can categorize the collective behaviour (the question to be asked: what happen when you take one part apart?)
 - ◆ 1- Material, 2- Plant, 3- Animal
- Flock example
- Boundary of a system (a complex system is a system) is function of the observer.

- Hot topics
 - ◆ Evolution, altruism
 - ◆ Connection; genetic networks
 - ◆ Spatio-temporal pattern behaviour
- Universality of concepts of Complexity Theory (valid for all domains)
- Paradox: robustness versus sensitivity
- Metrics: representation, description
- Subjectivity of the description = function of needs, observers
- Scale – lens – zoom
- Collective complexity > individual complexity (not necessarily true)
- Interdependence between individuals is manifest
- Complexity -> number of choices
- Tool: a balance between complexity and scale (complexity profile)
 - ◆ Wolf and baseball boy example
 - ◆ Iraq example
- Suggested methodology: 1- identify goals, draw the complexity profile and then identify appropriate forces
 - ◆ Littoral example
 - ◆ Open ocean->large scale
 - ◆ Urban->smaller scale
- Requisite variety (Ashby)
- COP: each person should have the information they need to have, not the whole information
- Attention: integration is a buzz-word
- Predictability of complex systems, chaotic systems
- Space of possibility
- Space of problems
- Space of solutions
- Example of medical prescriptions
- Double the information to lower errors
- Example of the hospital
- Problems happen at the level of team

- Suggested methodology: see how things are organized, make a deep analysis, identify weak parts, take appropriate actions
- Creation of complex systems-> consider evolution of this system, it will evolve continually, nothing is fixed
- A list of major complex projects that failed
- Standish: 20% success, 50% challenge, 30% impaired
- Proposed methodology: 1- Recognize all aspects of complexity, when this is not enough, 2- consider the dynamics of the evolution
- Evolution in Systems Engineering
- When the level of complexity is high, tests are impractical
 - ◆ Example of Intel
 - ◆ Skinner box
- Example of Air Traffic Control
 - ◆ Solution: double terminal (one new with one old), one terminal at the time. This is similar to the doubling within chromosomes.
 - ◆ Incremental and redundant replacement
- Build systems around changes, evolutions. Requirements will always change. It is a new way of thinking.
 - ◆ How to build process in which the system is built (meta-process)
 - ◆ Create context, design process
 - ◆ Develop parallel iterative incremental scheme (evolutionary process)
 - ◆ Constraint only when necessary
 - ◆ Simplify whenever it is possible
- Attention: dogma.
- Need for education on on-going transformation
- Suggestion: start where you are, setting goals is not the answer, learn lessons learned
- MAP the space problem, where we are: where do you want to go?
- Proposed methodology:
 - ◆ 1- Pattern of collective behaviour (large scale). Get the big stuff written first, go to smaller scale after
 - ◆ 2- Understand complexity. What can be done, what cannot be done, understand what is beyond our capacity
 - ◆ Details at small scale will have impacts on larger scale details
 - ◆ What aspects of the system should be controlled, is it a distributed control?

- Team: how to make a team
 - ◆ Put people under fire, under pressure
 - ◆ Put people in competition
 - ◆ That is what evolution is all about
 - ◆ Keep what is successful, remove what fail
- Evolution: competition + collaboration: relationships between these two
- Team at level 1: individual
- Team at level 2: team, collective
- Competition at one time scale is collaboration at longer time scale (competition causes cooperation through selection) and cooperation enables competition
- Rules within each individual must take into account these considerations

2.2 The ½-day workshop

On December 8th AM, participants of the Complexity Tutorial/Workshop 2006 were invited to attend a 1/2 –day workshop. The main goals of this ½-day workshop are described in the following lines.

- Make a quick review of concepts presented by Professor Bar-Yam.
- Capture comments of participants on Professor Bar-Yam Tutorial.
- Propose participants a working methodology.
- Identify new avenues of collaborations between DRDC-RDDC organizations.
- Identify new avenues of R&D that will involve these organizations.

Robert Charpentier leaded the ½-day workshop. He first presented the methodology. This methodology is summarized in the following lines.

- 1- State-of-the-Art report
 - ◆ Internal study and Invited expert
- 2- CF requirement scoping study
 - ◆ Evaluation of the State-of-the-Art
 - ◆ Identification of main R&D avenues
 - ◆ Prioritization and organization of efforts
- 3- Feasibility study
 - ◆ Technological options, \$, time , risk
 - ◆ 2 - 6 month effort
- 4- Funding – Partnership & client presentations

- 5- Research project
 - ◆ 1 - 3 year effort with annual delivery
- 6- Publications, Demonstrations, Delivery etc

Phase 1 consisted of a State-of-the-Art on Complexity Theory, chaos and complex systems. This work is already made in Couture (2006 a, b, c and d) and Poussart (2006). An internationally recognized expert (Professor Bar-Yam) was then invited to give us a Tutorial on complexity (the CTW-2006 Tutorial).

Phase 2 started during the ½-day workshop and it is on-going. The State-of-the-Art was already evaluated by some internal/external people; we will also get an evaluation of Couture (2006d) by Professor Bar-Yam. Participants are strongly invited to give their comments on these documents.

Six avenues of R&D were also identified; they are listed and briefly described in Section 3.6. Prioritization and organization of efforts will be done early in 2007.

Phase 3 is starting in January 2007. A feasibility study that was done in the past was provided on the CD-ROM as an example. It may help the building of our feasibility studies.

Phases 4, 5 and 6 are yet to come.

3 Outcomes of the CTW-2006 event

This Section summarizes some aspects of the main outcomes of the CTW-2006 event.

3.1 Questions of participants

Many questions were asked to Professor Bar-Yam during the CTW-2006 Tutorial. The following lines list many of them. This list is a transcription of Professor Bar-Yam notes on the paper board.

1. Complex systems under change (transformation, etc.).
2. When does emergent behavior appear? (self-healing)
3. How can we describe model/emergence?
4. What are the levels of detail to look at?
5. What does complexity tell us about? (EBO, Netcentric, etc.)
6. What about scales in time?
7. How can we achieve agility?
8. What about complex environments? We grow headquarter. Need smaller organizations, share products.
9. Add variety, change but maintain old capabilities, how do we do this?
10. How to harmonize complexity between allied systems?
11. Use complexity Profile to predict new disruptive technologies.
12. What is the impact on Complexity Profile of separation parts and defining interfaces?
13. How to model complex systems? How to ascertain the models are meaningful?
14. May be we are too pessimistic and Google search will enable us to individually understand science.
15. Inevitability of increasing complexity?
16. Raising the level of complexity, raising capability. How do we know/recognize?
17. How does complexity in line with control?
18. What are successful adaptive strategies?

19. Complex systems used to solve computer related problems?
20. How computers help with complexity? Ex: “Google search”
21. How do we develop tools (what tools) to help us (direct and indirect effects)?
22. Capability of teams to help understand challenges?
23. What to control, understand, plan. How do a human deal with complexity?
24. How is Complexity Theory useful in counter agility?
25. What is the ideal framework that could be used to address complex problems?
26. How to explain complexity to military clients?
27. Are there other groups, institutes that work on Complexity Theory?
28. Are there complexity groups in Europe?
29. Say a few words about: NECSI, courses, actions, ...

3.2 Comments on the tutorial

A number of comments were formulated by participants during the ½-day workshop. The following lines are a random list of them.

1. For some participants the level of details and the depth of Professor Bar-Yam explanations were appropriate. For other participants the explanation could have been deeper, he could also have provided more details.
2. The explanations were often philosophic, this was probably necessary.
3. Professor Bar-Yam did not present a lot of concepts of Complexity Theory.
4. Some people were new to Complexity Theory. They learned significantly from the Tutorial.
5. Some people liked the multidisciplinary aspect of the Tutorial.
6. An example to follow (the CTW-2006).
7. Professor Bar-Yam did not present many examples. The ones that were presented were may be too simple.
8. We must look at the impact on Forces Capability.
9. The Tutorial builds a foundation that can be used to validate other things. It gives us a common language and where it makes sense.

10. This theory (or science, or art, or science of reality) needs to be fully explored and understood.
11. We need a common lexicon.
12. The Tutorial could have been a little bit more structured.
13. Some people mentioned that they already knew what was presented; it is the common sense that is formulated in another way. What is new in this theory is not yet clear.
14. Some participants mentioned that the CTW-2006 event reached its goals. It raised a lot of questions and discussions, many people learned on the problems associated with “complexity” in military contexts, the event generated new collaborations among DRDC-RDDC people, etc.
15. Professor Bar-Yam could have answered the questions using more in depth explanations. Many participants mentioned that the modeling and simulation aspects of complexity were not addressed appropriately by Professor Bar-Yam.
16. This event allowed participants to identify new requirements for future training.
17. Management should be aware of this science. But who should know what?
18. There was an agreement that these concepts of Complexity Theory are and will be important or necessary.
19. What was presented is one view of Complexity Theory; the one that Professor Bar-Yam uses in his work. There are many others in the scientific literature. We did not have the complete integrated view of Complexity Theory, probably because it does not exist yet.
20. Professor Bar-Yam had to make a choice between deep theoretical explanations and very wide superficial explanations. His choice allowed all people to understand what was presented. The answer of certain questions would have needed a lot of time, and we had only two days.
21. The writer of this document adds that Professor Bar-Yam insisted on the importance of posing the problem, the importance of “thinking complex” instead of “thinking reductionism”. When participants were asking questions, he often told them “what is exactly your question”, “are there other ways of formulating it”? He transformed asked questions trying to identify its true nature, the true nature or sources of the problem.

Questions and comments showed that participants were highly interested by the subject. Professor Bar-Yam also mentioned that all questions and comments were very pertinent.

3.3 New avenues of national collaborations and R&D

A number of different avenues of collaborations and R&D were proposed to participants during the ½-day workshop. Six were retained, Table 1 lists them.

Table 1. Six avenues of R&D

	Title	CF Motivation	Opportunities	Team Leaders
1	Assessing Quantitatively Mission Complexity	- Help the CF avoid engaging in mission unlikely to succeed - Optimize capabilities for mission success	- Maybe some CF forces planning scenarios? - CX profile to quantify evolutive/disruptive technologies - Complexity measures to determine the feasibility of the integrated management readiness capability	- Valcartier: Mario Couture - CORA: David Connell - CFD: Len Goodman
2	Understanding Non-Traditional Opponents	Improving peacekeeping and peacemaking OPS where opponents are not structured in pyramidal C2	- Review SA S&T in the light of self-organizing opponents - (Networked) crowd behaviors? - Effectiveness of psychosocial ops to influence opponents - Rules of engagement with non-lethal weapons for crowd control	- Toronto: David Mandel and/or Len Goodman - CORA: Steve Flemming, Paul Massel
3	Redundant Low BW Networks	Improving information exchanges under limited communications channels	- Self-adapting redundant networks - BW-independent robust networks with graceful degradation	Valcartier: Nawel Chefai
4	Non-Traditional Organizations for the CF	Help the CF evolve into a self-organizing structures for modern theatre	- Simulate self-organizing forces against non-hierarchically organized opponents - Compare with current practices - Mapping social networks + overlays (real hidden leaders)	CORA: Paul Comeau
5	C2IS Evolutionary Design	- Design C2 to enable incremental, iterative system evolution - Need for agile and survivable systems	- Integrate CX add-on to redundant C2IS with diversity - Processes for evolutionary design	- Valcartier: Mario Couture - CORA: Paul Comeau
6	Lessons Learned from Doctrine Shortcomings?	- Agility in conducting operations - Knowledge and lessons learned	- S&T support to ops - Battlefield adaptability	- CORA: David Connell

3.4 Supplementary material – The CTW-2006 CD-ROM

One CD-ROM was given to all participants at the end of the event. This CD-ROM contains additional information that will be useful for our next efforts. Table 2 lists and describes the content of this CD-ROM.

Table 2. Content of the CTW-2006 CD-ROM.

Repertory	Description of Files
Dr. Bar-Yam Documents	Four documents that describe the content of the Tutorial.

Dr. Poussart Documents	A State-of-the-Art on Complexity that was made by Dr. Poussart in 2006.
DRDC-RDDC Valcartier Document	Four documents of an extensive State-of-the-Art on Complexity Theory, chaos and complex systems that was made by Mario Couture in 2006.
Example of a Feasibility Study	An example of a feasibility study that may help our next efforts. This file was given by Robert Charpentier.
Invitation to the CTW-2006	The three invitation files that were sent to all participants.
Pictures of the Event	Some pictures that were taken during the event.
Presentation – R. Charpentier	The presentation Robert Charpentier made on December 8 th . Actually, this is a working presentation. It is not part of the CD-ROM but it was sent separately by email to all participants.

3.5 Comments on the CTW-2006, and contributors

Many comments from participants as well as Professor Bar-Yam were made regarding the organization of the CTW-2006 event. They were all positive. The following lines list some the contributors that made possible this event. The writer of this document wants to express his profound gratitude to these people.

- Robert Charpentier: he was a mentor and advisor
- Capt Marc Quintin: invitation messages, welcoming people at the gate
- Mélanie Brousseau: organized the classroom, coffee break
- David Ouellet: the photographer
- Richard Carbone: Richard burned the CD-ROM we gave you Friday morning
- Richard Côté: security, fax, photocopy, key, and many others
- Afaq Ahmad: help find financial support, organize the event
- **Guy Turcotte (SdS): financial support**
- **Clem Laforce (DST-POL): financial support**
- **DRDC-RDDC Valcartier**

The success of this event is the result of a team effort.

3.6 Valcartier Online and Leo Online

The draft of a text describing the event was sent to Valcartier Online and Leo Online. It should be published on December 15th, 2006. The French version of this text is reproduced in the following lines.

Trente personnes provenant de différents organismes de la DRDC-RDDC ont participé à l'événement « Complexity Tutorial/Workshop 2006 » a eu lieu les 6, 7 et 8 décembre à Valcartier.

Le professeur de réputation internationale et président du « New England Complex Systems Institute » (<http://necsi.org/>), Dr. Yaneer Bar-Yam, a été invité à donner aux participants un tutorial de deux jours sur la Théorie de la complexité et ses possibles applications dans les domaines médical et militaires. Cette formation qui visait principalement à proposer aux participants la description d'un nombre sélectionné de concepts de cette théorie a suscité beaucoup d'intérêt. La troisième journée, les participants ont été invités à participer à un atelier qui visait à faire une revue rapide des notions apprises, à évaluer le cours et à identifier des avenues de collaboration et de R&D.

L'événement a été un vif succès à tous les points de vue. Le tutorial a suscité beaucoup de questions et discussions pertinentes et intéressantes. Le niveau du cours a permis tant aux personnes novices qu'aux personnes plus au fait de cette théorie d'avoir le niveau de connaissances minimum leur permettant de contribuer à toutes les discussions. L'atelier a également donné lieu à des échanges et discussions qui ont permis d'identifier et démarrer de nouvelles collaborations dans six domaines courants de R&D de la DRDC-RDDC.

L'événement était organisé par Mario Couture et Robert Charpentier. Un CD-ROM contenant de l'information additionnelle a été remis à tous les participants. Les personnes intéressées par cette information peuvent communiquer avec Mario Couture à l'adresse suivante : Marco.Couture@drdc-rddc.gc.ca.

Merci aux participants, merci également aux collaborateurs (Capitaine Marc Quintin, Mélanie Brousseau, David Ouellet, Richard Carbone, Richard Côté) et plus particulièrement, merci pour le support financier sans lequel cet événement n'aurait pu être possible (Guy Turcotte ; SdS et Clem Laforce ; DST-Pol.).

4 Concluding remarks and future works

The Complexity Tutorial/Workshop 2006 was a complete success. All initial goals of the Tutorial and the Workshop were reached.

Next lines list some milestones that were determined during the workshop.

- Dec-Jan 2006: Teams are formed and quick evaluation
- Jan-June 2007: Feasibility study (v1)
- June 2007: Presentation and evaluation
- July-August 2007: Complementary studies (v2)
- Fall 2007: Project (s) proposed for funding

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Annex A – List of participants

Table 3. List of participants

Names	Emails
Ahmad Afaq	Afaq.Ahmad@drdc-rddc.gc.ca
Auger Alain	Alain.Auger@drdc-rddc.gc.ca
Bernier François	Francois.Bernier@drdc-rddc.gc.ca
Boury-Brisset Anne-Claire	Anne-Claire.Boury-Brisset@drdc-rddc.gc.ca
Charpentier Robert	Robert.Charpentier@drdc-rddc.gc.ca
Chefai Nawel	Nawel.Chefai@drdc-rddc.gc.ca
Comeau Paul	Paul.Comeau@drdc-rddc.gc.ca
Connell David	Connell.DP@forces.gc.ca
Couture Mario	Mario.Couture@drdc-rddc.gc.ca
Ducharme Michel	Michel.Ducharme@drdc-rddc.gc.ca
Emond Ed	Ed.Emond@drdc-rddc.gc.ca
Goodman Len	Len.Goodman@drdc-rddc.gc.ca
Hughes Steven	Steven.Hughes@drdc-rddc.gc.ca
Kollenberg Klauss	Klaus.Kollenberg@drdc-rddc.gc.ca
Larochelle Simon	Simon.Larochelle@drdc-rddc.gc.ca
Lecocq Régine	Régine.Lecocq@drdc-rddc.gc.ca

Lizotte Michel	Michel.Lizotte@drdc-rddc.gc.ca
Massel Paul	Paul.Massel@drdc.rddc.gc.ca
Michaud Frédéric	Frederic.Michaud@drdc-rddc.gc.ca
Mokhtari Marielle	Marielle.Mokhtari@drdc-rddc.gc.ca
Poussart Denis	Poussart@gel.ulaval.ca
Quintin Marc	Marc.Quintin@drdc-rddc.gc.ca
Rioux François	Francois.Rioux.LTI@drdc-rddc.gc.ca
Salois Martin	Martin.Salois@drdc-rddc.gc.ca
Stemate Luminita	Luminita.Stemate@drdc-rddc.gc.ca
St-Jacques Jean-Claude	Jean-Claude.St-Jacques@drdc-rddc.gc.ca
Tremblay Jocelyn	Jocelyn.Tremblay@drdc-rddc.gc.ca
Turcotte Guy	Guy.Turcotte@drdc-rddc.gc.ca
Verdon John	Verdon.JBV@forces.gc.ca

Annex B – Syllabus of the Tutorial and reference material

Syllabus

Day I:

1. Introduction: Examples, questions, and methods
2. Interactions and Pattern Formation
3. Collective Behaviors
4. Example: modeling ethnic violence
5. Networks: Network structures and behaviors

Day II:

1. Describing Complex Systems
2. The space of possibilities, multiscale representation and complexity profile
3. Example: Quantifying complexity of military conflict
4. Example: Terrorism and security
5. Natural complex systems and evolution
6. Complexity of engineering projects
7. New paradigms for complex systems engineering

Reference Material

The recent book “Making Things Work: Solving Complex Problems in a Complex World” can be ordered at: <http://necsi.org/publications/mtw>

Additional scientific papers from Dr. Bar-Yam and his books “Dynamics of Complex Systems” are available at: <http://www.necsi.org/research/>.

Annex C – Pictures of the CTW-2006 event

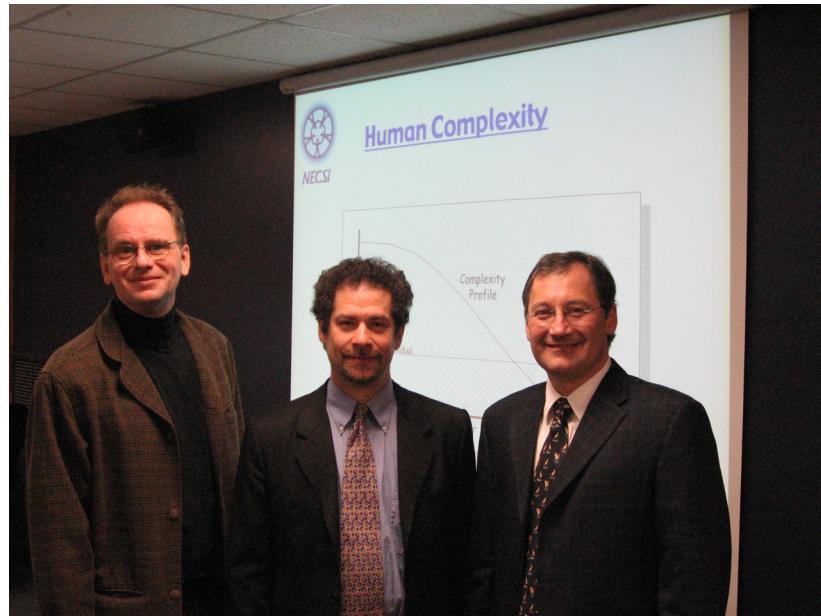


Figure 1. From left to right: R. Charpentier, Y. Bar-Yam and M. Couture.



Figure 2. The CTW-2006 classroom.

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This document provides a description of the Complexity Tutorial/Workshop 2006 event that was held on December 6th, 7th and 8th, 2006 at DRDC-RDDC Valcartier. Outcomes of the event, future works and conclusions are included.

Ce document donne une description de l'événement « Complexity Tutorial Workshop 2006 » qui a eu lieu les 6, 7 et 8 décembre 2006 à DRDC-RDDC Valcartier. Les résultats de l'événement, travaux futurs et conclusions sont également inclus.

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